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MARGINAL KAMES.[1]

BY H. CARVILL LEWIS.

Introduction.—During the course of an investigation, in 1881, of the extreme southern edge of the great ice-sheet in Pennsylvania, as marked by its *terminal moraine*, the writer had an opportunity of studying several phenomena produced by the glacier along the line of its southern terminus; one of the most interesting of which phenomena were certain short hummocky ridges of stratified drift, which, often closely connected with the terminal moraine, appear to belong to a class of surface deposits elsewhere called *Kames.*

The kames of Scotland, the *Eskers* of Ireland, and the *Åsar*, or *osars*, of Scandinavia, all closely related, if not identical, deposits, find an analogue in the ridges of stratified drift which have been described by a number of geologists as occurring in northeastern America, including Canada.

They may be described as narrow ridges of stratified, water-worn, generally sandy drift, which, sometimes forming a series of tortuous and reticulated hills, sometimes a nearly regular straight ridge, and often forming knob-like conical hills ("hummocks"), alternating with similar conical depressions ("kettle-holes"), generally lie along valleys or depressions, and have a general downward slope from a higher to a lower level.

These gravel ridges are generally quite steep—as steep often as the nature of the material will allow. This steepness is quite striking to a geologist accustomed to the gentle slopes of the gravel formations in the non-glaciated portion of this country, and at once suggests the *recency* of their origin.

The internal structure of kames is in general anticlinal. "Flow-and-plunge" structure, and oblique lamination, the evidence of rapid fluviatile action, is often seen in their interior; and as a rule the material is finest in the interior, and most coarse on the exterior portions of the kame.

Wherever along the course of the terminal moraine the writer has had an opportunity of examining recently made transverse sections of these drift ridges, he has found clean water-worn sand within, showing distinct torrential action, and a coarse gravel on the outside. Sometimes, but rarely, large boulders lie on top of the kames. The writer has never observed large boulders within them. The material is generally small, and well water-worn and rounded, showing no glacial scratches on its pebbles, and for the most part is of local origin.

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[1] Read before the British Association for the Advancement of Science, Montreal, August 29, 1884.

The contours of these kames in their "hummocky" appearance, are very like those of moraines. Indeed, it is often impossible to distinguish kames from moraines by external features alone. When, however, we take into consideration their structure and their position, they cannot readily be confounded. Their distinguishing characters are (1) their internal structure, kames being distinguished by an absence of till and glaciated pebbles, and by stratified, generally anticlinal, structure—all of these characters being very different from the unstratified pell-mell character of moraines; (2) their geographical position and the influence of the surrounding topography upon them. Topography has practically no influence on the moraine of the great glacier. The terminal moraine on the Pocono plateau closely resembles that in Cherry Valley, 1000 feet below it; and the moraine at the height of 2500 feet, in central Pennsylvania, cannot be distinguished from that in New Jersey, at the sea-level. The moraine may lie on the downward slope of a hill, as at Fishing Creek, Columbia Co.; may form a dam across a creek, as at Cole's Mills, or it may stretch transversely across a mountain ridge such as the Kittatinny Mountain.[1]

On the other hand, kames as a rule depend directly upon topography. While they do not always coincide with the present drainage systems, they extend from higher to lower levels. They follow valleys generally along the central line, but sometimes, indeed, rising over considerable elevations. Where the valleys are distinct and sharply defined by high ridges on either side, the kames are confined to them, and follow more or less closely the modern water-courses; but where, as in southeastern Massachusetts, the valleys are not well marked, and there is no defining wall, the country being nearly level or rolling, and there being no mountain ranges, kames often cross where there are now no water-courses, even crossing rivers, as may be seen on the Merrimac at Lawrence, which is said to be crossed at right-angles by a kame.[1] In no sense, however, can kames be regarded as the work of rivers merely. For, as Prof. Stone has shown so clearly in Maine, they sometimes rise out of a valley and pass through a gap in the hillside or cross a ridge perhaps 150 feet high, to low grounds beyond. Prof. Stone has in several cases followed them *up-hill* for a short distance.

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[1] This independence of the terminal moraine as regards topography, is prominently brought out in the detailed description of it given by the writer in Report Z, Second Geological Survey of Pennsylvania.

Such facts may best be explained by the supposition that the stream of water which formed them must have either been enclosed within high walls of ice, or have flowed in a subglacial tunnel.

Literature.—A large number of kames, occurring under various conditions, have been observed in different portions of the glaciated area of North America. None occur south of that area.

As long ago as 1842, Dr. Edward Hitchcock described a series of gravel ridges which pass through Andover, Mass., and which is known locally as "Indian Ridge." At that time he regarded this ridge, composed, as he well described it, "of a collection of tortuous ridges and rounded even conical hills with corresponding depressions between them,"[2] as a species of moraine. These have been more recently studied in detail by Prof. G. F. Wright,[3] who has shown that they form part of a chain of such ridges, many miles in length, running from Franklin, N. H., to Malden on the ocean, and are true kames.

The most complete studies of kames in this country are those made by Prof. Geo. H. Stone,[4] who has mapped some thirty-one linear systems of kames in the State of Maine, all running from the high interior of the State southeastward toward the sea. He describes them as meandering like rivers in their course from the mountains oceanward. They start sometimes at elevations as high as 1600 feet above the ocean, they freely cross low transverse hills 100 feet high, but not 200 feet high, and they have a strong inclination to keep within straight lines, notwithstanding minor obstacles. These ancient gravel streams were not so easily turned from their course as streams of to-day. When once in a valley coinciding with the main direction of the kame, the latter is apt to keep in it. Prof. Stone states that these long ridges are homologous with the Scandinavian Osars, rather than with the short ridges classed as kames.

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[1] Wright, Proc. Bost. Soc. Nat. Hist., xix, 47.

[2] Trans. Am. Assn. Geol. and Nat., 1841–2, p. 191.

[3] Proc. Bost. Soc. Nat. Hist., Dec., 1876.

[4] Kames of Maine. Proc. Bost. Soc. Nat. Hist., xx, 430, 1880.

In other parts of New England, kames have been described by several authors. In New Hampshire, Prof. C. H. Hitchcock and Mr. Warren Upham have made noteworthy contributions to this subject. In vol. iii of the New Hampshire Geological Survey, Mr. Upham has contributed a valuable chapter on surface deposits, among which the most important are the numerous kames. One of these, described by Mr. Upham as occupying the valley of the Connecticut River, has subsequently been studied by Prof. Dana, who believes[1] that it is merely a portion of the terrace formation in that valley, and that the name of kame should not properly be applied to it. Prof. Hitchcock,[2] however, has subsequently examined a critical locality in the Connecticut Valley, and finds the arched kame-gravel dipping beneath a horizontal terrace-loam, thus showing the greater age and different origin of the kame, and supporting Mr. Upham's views.

Prof. J. S. Newberry[3] and Prof. N. H. Winchell have described kames in Ohio, where they are known locally as "hog-backs.' Prof. Newberry at that time regarded them as due to the action of breakers and shorewaves at a period when the region was submerged under an inland fresh-water lake. Kames and kame-like ridges have also been described in Michigan and in Minnesota. In Canada, Sir William Dawson[4] has described certain ridges known as "Boar's-backs" and "Horse-backs," which he regards as eskers. One of these, in Cumberland, is a narrow ridge, so level on top that it forms a natural carriage-road for eight miles; another one, in Shelburne County, is a long ridge, also used as a carriage-road; while shorter and more interrupted ridges occur in a number of places. Sir William Dawson remarks that they bear no resemblance to glacial moraines, and believes that they were thrown up by "the surf or marine currents and tides." Prof. T. C. Chamberlin[5] has given an excellent description of kames associated with terminal moraines in Wisconsin and elsewhere, and his paper contains a good reference list to the literature of kames. The kames described by him differ from those described in the present paper in being knob-like hills, "simple isolated mounds," or clusters of such mounds, rather than linear ridges, and also in lying transverse to the glacial movement, which is not the case with the Pennsylvania deposits.

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[1] Am. Jour. Sc., xxii, 451, 1881.

[2] Proc. Am. Assn. Adv. Sc., xxxi, 325, 1882.

[3] Geol. Surv. of Ohio, vol. ii, p. 41-47.

[4] Notes on the Post-Pliocene Geol. of Canada, 1872, p. 40.

[5] Hillocks of angular gravel and disturbed stratification. Amer. Jour. Sc., xxvii, 1884, p. 378.

Origin of Kames.—The early view of geologists as to the origin of kames, was that they were washed into shape by the waves and currents of the ocean. This was the view held by Dr. Jas. Geikie in the first edition of his "Great Ice Age,"[1] and was formerly advocated by many geologists both in Europe and America. But recent researches have shown that this view is untenable, and in the second edition of Dr. Geikie's book kames are regarded as the work of subglacial rivers.[2]

The researches of American geologists, especially the work in New England of Upham, Wright and Stone, have shown the occurrence of kames in positions out of the reach of oceanic currents. When marine deposits occur, as they do along the border of New England, in the St. Lawrence Valley, and elsewhere, they are seen to be horizontally stratified sands and clays often holding marine fossils, and clearly overlying the kame ridges. The terrace material of flooded rivers is also observed to overlie the kames.

On the other hand, kames are newer than glacial till, and overlie and swing around the drumlins of Massachusetts. These "drumlins," like those described by Kinahan and Close in Ireland,[3] are low oval hills, composed of unstratified glacial till, and are most satisfactorily explained as lenticular ground moraines formed under the ice sheet during its advance. They have been called "lenticular hills." Their longer diameter is generally parallel to the direction of the ice flow, as shown by neighboring striæ, and they appear to be of a mid-glacial age.[4]

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[1] Page 229.

[2] Page 217, etc.

[3] Glaciation of Iar-Connaught, Kinahan and Close, 1872.

[4] For discussion of "lenticular hills," see papers in Proc. Bost. Soc. Nat. Hist., by N. S. Shaler (xiii, 196), and by C. H. Hitchcock (xix, 63), and Geol. Survey of N. H., iii, p. 287; also, an article by W. M. Davis, Science, iv, 419.

Kames, therefore, would appear to be intermediate in age between the time of the deposition of the till or ground moraine and the age of the terraces and marine deposits. Mr. Upham[1] regards them as due to rivers flowing in channels formed upon the surface of the ice near its retreating edge. As the wall of ice on either side disappeared at the final melting of the ice sheet, the gravel and sand remained in long ridges or in mounds. He believes that kames were formed at or near the mouths of these surface streams, extending along the valley as fast as the ice front retreated.

Prof. G. F. Wright[2] believes that in many cases they are due to the sliding down from the surface of the ice of morainic debris accumulated near its end, so that they may represent medial moraines. He shows that they do not lie in channels worn in the till, and that very often they are unstratified, and thinks that the material composing them may have first formed lines upon the top of the ice. But, as Prof. Stone has shown, it is only among the highlands that the material of kames are poorly stratified ; as soon as open valleys are reached the materials are worn, rounded and stratified.

Quite recently Prof. T. C. Chamberlin, of the U. S. Geological Survey, in an important paper " On the Terminal Moraine of the Second Glacial Epoch,"[3] proposes to separate kames from "Åsar," regarding kames proper as *tranverse* to the slope of the surface, the course of the valleys and the direction of the drift movement,"[4] while the term åsar is employed to designate long river-like ridges of gravel. Åsar are described as extending " from higher to lower levels, following in general but not in detail the course of the greater valleys and the direction of glacial striation." As stated elsewhere,[5] they are held to be " the products of the drainage system of practically extinct glaciers."

This is practically the view of Professor Stone, and of other recent workers in this field, as it is that of the present writer. Moraines are the product of the *advance* of the ice-sheet, osars and kames of its *retreat.* If the distinction between osars and kames be sustained, the deposits described in the present paper might more properly be called "*marginal osars.*" In many characters, however, they are intermediate between osars and kames as defined by Professor Chamberlin.

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[1] Geol. of N. H., vol. 3, pp. 14–176.

[2] Proc. Bost. Soc. Nat. Hist., xx, 219.

[3] Third An. Rep. U. S. Geol. Surv., p. 295, etc.

[4] *Loc. cit.*, p. 300.

[5] Amer. Jour. Sc., xxvii, 378.

Kames are shown by the same authority to be composed of material derived from the adjacent till, and of local derivation, and from a study of their topographical situations and other features, the just conclusion is drawn[1] "that these hills could not have been produced by any form of beach action, whether assisted by ice or not," but that "they were formed along the edge of the ice-sheet by numerous marginal streams."

Prof. Chamberlin makes these kames "associates if not constituents of terminal moraines;" and classes them among moraine deposits. He says,[2] "It is my belief that they were due to special aqueous action attending glacial advances in such close relationship that they become distinctive incidental products, and mark the position of halt and retreat, as characteristically as the true moraines of mechanical origin themselves, which they so often overlie and conceal."

He therefore regards certain stratified knob-like hills of gravel in western and central New York State as representing a true terminal moraine of the second glacial epoch, and he has traced such a *kame-moraine* from Chautauqua Lake to the Mohawk and Catskills. These lines of hills he regards as representing the boundary of the great ice sheet at the period of its longest halt. He says that this inner morainic belt is "more massive and pronounced in development than the moraine referred to the older epoch,"[3] and "that its surface is fresher and less subdued by meteoric modification."

Granting that the line of kames so carefully traced out by Professor Chamberlin is correctly interpreted as representing a halt in the retreating ice-sheet, the present writer holds that, on account of their stratified character, such gravel deposits should not be identified with the unstratified masses of glacier-made till which constitute the true terminal moraine. The one is due to water action, the other to ice action. The term *kame-moraine* is, in the opinion of the writer, a more appropriate name for such deposits than terminal moraine, which latter term would then be kept to designate the extreme outer mass of debris pushed out or dropped by the glacier at the time of its farthest extension.

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[1] *Loc. cit.*, p. 387.

[2] Third An. Rep. U. S. Geol. Surv., p. 376.

[3] *Loc. cit.*, p. 346.

That kames may be associated with the terminal moraine, is a fact which the writer will endeavor still further to demonstrate. But that they are distinct from it in structure, origin, and significance, will, it is believed, be granted after a careful consideration of the facts observed in Pennsylvania.

Marginal Kames in Pennsylvania.—That the terminal moraine separating the glaciated from the non-glaciated district has, throughout the greater part of its course in Pennsylvania (Plate III), an essentially unstratified character, has been sufficiently demonstrated in the author's report describing it.[1]

It has been shown that even where crossing river-valleys its unstratified condition is maintained; as, for example, opposite Belvidere in the Delaware, and at Beach Haven on the Susquehanna, at both of which places it is clearly distinguished from the stratified material lapping up against it. But immediately back of the moraine there occur in many places other stratified deposits, which, although similar in contour to the moraine proper, are worthy of separate consideration.

The class of kames which it is now proposed to describe, have, the writer believes, not heretofore been recognized in their true significance. These are either directly connected and continuous with the terminal moraine in Pennsylvania, or they are in such close proximity to it that they may properly be known as *marginal kames*. This term is given in order to distinguish them from longer kames or osars which may have no relation to the margin of the ice-sheet. None of them are transverse to the motion of the glacier, like a moraine, unless the drainage makes them so, and in this respect they do not answer to the definition of a kame given by Prof. Chamberlin, but have distinct characters of their own. They are all short, from a few hundred feet to a few miles in length, and they all follow the direction of the drainage. They have a general downward slope, and all lead toward a river-valley or other water-course. All those observed are made of water-worn materials, and where sections can be obtained show an anticlinal structure within. As already stated, their materials are finer in the interior, and most coarse in the exterior, and sometimes, though rarely, large boulders lie on the surface. The comparative shortness of their courses distinguish them from the long river-like osars. Their origin and significance can best be appreciated after a description of a few of them in detail. The accompanying map gives their general position with regard to the terminal moraine.

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[1] Report Z, Second Geological Survey of Penna.

There are three kames in Northampton County, Pa., which are especially instructive. The most prominent of these is that which traverses the centre of Mt. Bethel Township in a northeast direction, follows approximately the valley of Jacobus Creek, and ends upon the banks of the Delaware at Portland.[1]

This kame, which has been mistaken for the terminal moraine,[2] is composed of a series of interlacing ridges and hummocks, often enclosing kettle-holes, and formed of stratified sand and water-worn gravel, carrying occasional rounded boulders upon the surface.

The town of Portland is built upon the kame, which here rises 100 or more feet above the river, forming a prominent hill. Some fine railroad cuts, through several ridges of the kame, 2½ miles from Portland, show it to consist of a stratified sand overlaid by a boulder-bearing clay, or till, as though it had been formed by running water *beneath* the ice, which on melting dropped the till. At this place, one mile southeast of Roxborough (Johnsonville P. O.), the kame is composed of a series of reticulated ridges, enclosing typical kettle-holes. One of these, known locally as the devil's kettle, and supposed by some to be an old Indian fort, is a symmetrical oval depression, surrounded by a raised rim, 300 feet long by 200 wide, and 30 deep. Like most kettle-holes, it has its longer axis parallel to the direction of the kame in which it lies. In the same neighborhood, similar rounded shallow depressions, with neither inlet nor outlet, lie upon the very summit of sandy ridges 100 feet above the level of the surrounding country.

These kettle-holes do not appear to be the result of natural erosion, and they are in no way allied to ordinary valleys or ravines, produced by the action of running water. The instructive fact that a raised rim frequently completely surrounds the kettle-hole, so as to elevate it above the surrounding country, is conclusive against any theory of ordinary erosion. In fact, the comparative *absence of erosion*, is one of the most remarkable facts relating to kames and their kettle-holes.

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[1] See Page Plates 8 and 9, in Report Z, pp. 53, 68.

[2] F. Prime, Proc. Amer. Phil. Soc., xviii, 85.

The kame here described is confined to the valley of Jacobus Creek. The high hills on the south are sprinkled with boulders, but hold no deposits of stratified drift.

The length of the kame is five miles. Its general elevation near Johnsonville is 600 feet above the sea, or 300 feet above the Delaware River at Portland; giving a northeastward slope to the kame of nearly 100 feet to the mile. It seems to have been caused by a stream, probably subglacial, draining *backwards* into the Delaware River at Portland. The direction taken by the stream producing the kame was just contrary to the direction of ice-flow, which was southeast. This kame is a good example of a *backward-draining* marginal kame.

Another locality which throws light on the origin of kames is in Upper Mount Bethel township, close to the base of the Kittatinny Mountain, and about a mile east of the moraine.

Here, on the road to the Fox Gap, a number of small, rounded, hummocky drift hills, and a series of ridges, irregularly interlaced with each other, composed of sandy water-worn drift within, but bearing upon their surface many boulders, form a fine series of small kames. These kames are not straight; they follow a curved line around Offset Knob.

Close to the flank of the mountain they bear south 20° west; somewhat lower and farther from the mountain, they bear south 30° west; still farther down the road, they veer yet more southwest. They seem to represent streams which, descending from the melting ice on the mountain, flowed at first southward, and then westward around Offset Knob, and, after issuing from the end of the glacier, emptied into the deeply flooded valley of Bushkill Creek, in Plainfield township.

Immediately north of these kames, a great accumulation of till and boulders forms a high ridge upon the side of the mountain. Most of the boulders are of Medina sandstone, but occasional boulders of limestone, and of fossiliferous rocks brought from the valley on the other side of the mountain, are found. This accumulation at a higher elevation than the series of kames represents the portion of the glacier whose melting supplied the kame streams. These small kames represented an outward drainage.

There are two curious little kames immediately south of Ackermanville, in Washington Township, Northampton County, which, though but miniature examples, have all the characters of larger kames, and offer a suggestion as to their origin.

Two small, straight, narrow ridges of stratified drift, 15 feet high and about 100 feet long, may be seen just below the village, running nearly at right-angles to the valley of the west branch of Martin's Creek. Both of these ridges run from the base of a hill west of the creek toward the stream, their direction being south 75° east; and west of each of them there is an opening in the hill, near the summit of which the moraine lies.[1]

Upon examining the structure of these ridges, as exposed by transverse cuts made by the railroad, they are found to be composed of fine stratified sand within and gravel without. The sand shows flow-and-plunge stratification, with a distinct anticlinal structure.

Here again the only satisfactory explanation is that they are due to subglacial streams which drained the melting edge of the glacier on the hillside *backward* into the subglacial valley, now occupied by the west branch of Martin's Creek. They are here at an elevation of 500 feet above the sea and about 190 feet below the edge of the moraine and are beautiful examples of miniature kames. An important point to note is that on placing the eye along the crest of each of these they are seen to be opposite small depressions in the hill on which the moraine rests. They are thus in precisely the position that would be occupied by the natural drainage of the edge of the ice-sheet.

The most interesting of all the kames of Monroe County are the curious conical hills and short ridges of sandy drift which lie along the centre of Cherry Valley, between the moraine and the Delaware River. A remarkable series of conical hills of peculiar and characteristic topography either stand singly, or (more generally) are connected one with another by irregular banks of gravel, to form a series parallel with the valley.

Near the Delaware Water Gap these hills rise often over 200 feet above the river, and often inclose basin-shaped depressions or kettle-holes. They are most abundant between Stormville and the river. Where the valley widens, just east of Stormville, two sets of kame-like ridges on either side of the valley have the form of a V.

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[1] See sketch-map in Report Z, p. 34.

Short *tributary kames*, whose axes are at right-angles to the main kame in the valley, appear opposite ravines or depressions in the hills bordering the valley.

A *buried kame* lies along the north and south valley of Broadhead's Creek, almost completely covered by subsequent deposits of terrace material. The *top* of the kame stands out of the level terrace plain which borders the creek at Stroudsburg and vicinity. A fine section of the buried kame at Stroudsburg shows its anticlinal structure and a *fault* in it caused by settling.

Another most interesting *buried kame* is in the valley of McMichael's Creek, in Hamilton Township, where the top of the kame appears through the sandy terrace plain which covers the valley. The kame runs along the centre of the valley while the creek wanders irregularly through it. The kames are clearly older than the terrace material.

Of the other kames and kame-like ridges of Monroe County, reference only need here be made to certain kames upon the summit of the Pocono plateau, which are of interest in draining *northward;* of these there may be mentioned the steep, sharp ridges of sand near Tompkinsville, Tolyhanna Township, which run toward lower ground northward, thus draining the glacial waters toward the Lehigh. These are immediately back of the terminal moraine.

Again, just west of the Lehigh River, and immediately north of the moraine, there appear kame-like ridges of sand and gravel in small valleys emptying into the Lehigh. These are *parallel to the moraine*, and are so simply because the drainage is here south of east, while the moraine trends to the northwest.

Below Scranton, on the Lackawanna River, and also on the Susquehanna, are long ridges of stratified sandy material, which are quite distinct from the terrace deposits of those rivers, and which appear to be portions of a kame similar to that described by Mr. Upham on the Connecticut River, and of similar origin. These cannot be classed among the marginal kames.

In "Pope Hollow," close to the line between South Valley township, Cattaraugus County, and Carroll township, Chautauqua County, N. Y., and resting upon the water-shed between Pope Run (a tributary of the Allegheny) and Case Run (a tributary of the Conewango), the moraine is finely shown as a ridge of till, which, stretching completely across the valley, and covered by numerous boulders of gneiss, rises upon the highlands on either side. The moraine ridge here, as in other places, is most prominent *behind* or toward the west.

A very small *marginal kame* runs westward and down-hill from the back of the moraine, in Chautauqua County, as though a subglacial stream had drained the moraine backward, into the valley of the Conewango. The moraine itself is apparently unstratified, and no drift was noticed in front (E.) of it. Its only drainage, therefore, must have been *backward*, into the Conewango.

An interesting *double kame*, consisting of two ridges of sand united into one, the double anticlinals being exposed, was observer by the writer in Mercer County.[1] It is probably not a true marginal kame.

An examination of the marginal kames, of which sufficient examples have now been given, leads, as has been seen, to the conclusion that they were made by *subglacial streams draining the edge of the ice-sheet.* The occasional boulders and till on top of, but not in, these kames argue a subglacial origin, the boulders and till having been dropped by the retreating glacier on the kames; while the position and direction of each of the kames described is just such as would be taken by streams flowing beneath the ice-sheet. Among the facts ascertained with regard to marginal kames are their water-worn and stratified character; their rude anticlinal structure, often of finer sand within than without; the presence of occasional boulders and even *till* on top of them; the absence of any fixed relation to the movement of the glacier; the general coincidence of their course with that of the natural drainage; the total absence of shells, driftwood, beach-marks, or other indications of the action of ocean currents, waves or tides; their intimate connection with the terminal moraine in such positions as to indicate a *backward*, as well as a forward subglacial drainage.

These kames are very different from those tongues of stratified drift which often occur in or near the glaciated region at the junction of two streams (ancient or modern). These deposits do not show an anticlinal structure, and instead of occurring in the centre of a valley, are seen at points where an eddy in the drift-laden waters, or more commonly the shelter of a projecting rock, has allowed them to be formed. They may be termed *eddy-ridges* or *terrace-deltas*, and are clearly of entirely different origin from kames. The writer has seen a number of such ridges in northern Pennsylvania, and there is little difficulty in distinguishing them from kames.

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[1] Report Z, p. 191.

That stratified deposits may exist beneath a glacier, undisturbed by the weight or motion of the ice, has been shown by observation at the base of the Swiss glaciers. Among the most interesting of these observations, because so well correlated with the phenomena of the American ice sheet, are those of Prof. Chamberlin, made at the base of the Rhone glacier. He remarks:[1] "At other points, near the centre of the valley, the ice may be seen resting directly upon well-assorted stratified sand and gravel. Level sheets of fine detrital matter extend without disturbance of continuïty or surface beneath the edge of the glacier. The assorting and stratification of this material was apparently accomplished by subglacial streams, which seem afterwards to have found other avenues, when the ice occupied their place either by settling down from above, or advancing from behind. The singular fact is that the stratified sands should not have been disturbed."

The similarity between the contours of kames and of moraines is accounted for on the supposition that both were moulded beneath the ice sheet. While the moraine shows the edge of the glacier, the kames indicate the direction of its drainage. Flat terrace plains, such as that at Berwick, on the Susquehanna, are made by floods issuing from the front of the glacier, but when the drainage was subglacial, whether forward or backward, kames are the result.

Subglacial Drainage.—The most important conclusion arrived at by a study of the *backward-draining* marginal kames is that of a great *subglacial drainage.* The same conclusion is drawn from observations on the terminal moraine itself, which in many places shows evidence of having been drained *northward*, not southward. Many such instances might be described.

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[1] Wis. Geol. Survey Report for 1878, p. 17.

On the high mountain plateau of Potter County, Pa., for example, at an elevation of 2500 feet, although the Allegheny River flowed at the very foot of the glacier, there is no drift in the valley of the river, and no indication of any drainage to the south; while north of the moraine the whole country is covered with clays, terrace plains, kames and every indication of the presence of both ice and water.

Again, in Columbia County, Pa., although Fishing Creek flows in front of the edge of the ice sheet which once rested on its eastern bank, there are no gravel deposits in the creek; while immediately back of the moraine we find them in great quantities, leading around to another outlet.

So on the Pocono plateau, in Carbon Co., the drainage was reversed; while in Northampton County, and Monroe County it was clearly in both directions, outward and inward.

The writer has adduced evidence that the Allegheny River, near Olean, N. Y., flowed into the glacier and out of it again in the same channel that it now occupies; flowing in a *subglacial* channel through or under a tongue of ice ten miles broad by two miles long.[1]

Everywhere there are indications of a great subglacial drainage. The observations of other geologists, especially of Prof. Newberry, in Ohio, lead to the same conclusion. Studies among modern glaciers confirm these interpretations of glacial phenomena.

Prof. Nordenskiöld described the "large and swift rivers," plunging from the surface into profound crevasses of the Greenland ice-sheet, and Dr. Rink speaks of the copious subglacial streams which flow out from under the Greenland ice.

From beneath the Muir glacier of Alaska,[2] there issues a subglacial stream 100 feet wide, and 4 feet in average depth, the flow being the same winter and summer. Prof. Dana[3] has rightly assumed that the ice sheet of North America would have had "subglacial streams as much more extensive than those of Greenland, as the precipitation was more copious and the drainage areas larger."

Much of the boulder clay and till throughout the lower portions of both the United States and Canada, shows evident aqueous action, not only subsequently to, but during its deposition.

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[1] Report Z, p. 154.

[2] Meehan, Proc. Acad. Nat. Sc. Phila., 1883, p. 249.

[3] Am. Jour. Sc., xxii, p. 366, 1882.

The great lake basins, and the St. Lawrence Valley, receiving subglacial streams from south as well as from north, may have been flooded with water while the ice still covered them.

Important deductions regarding the physical condition of the lowlands while covered by the glacier, and of the origin of certain aqueous varieties of till might be drawn from a further consideration of this subglacial drainage. The method of movement of a great glacier, a problem not yet fully understood, is also largely dependent upon the presence or absence of water beneath the ice.

The northward-draining marginal kames are undoubtedly but an insignificant portion of the widespread deposits made by the subglacial drainage which they indicate.

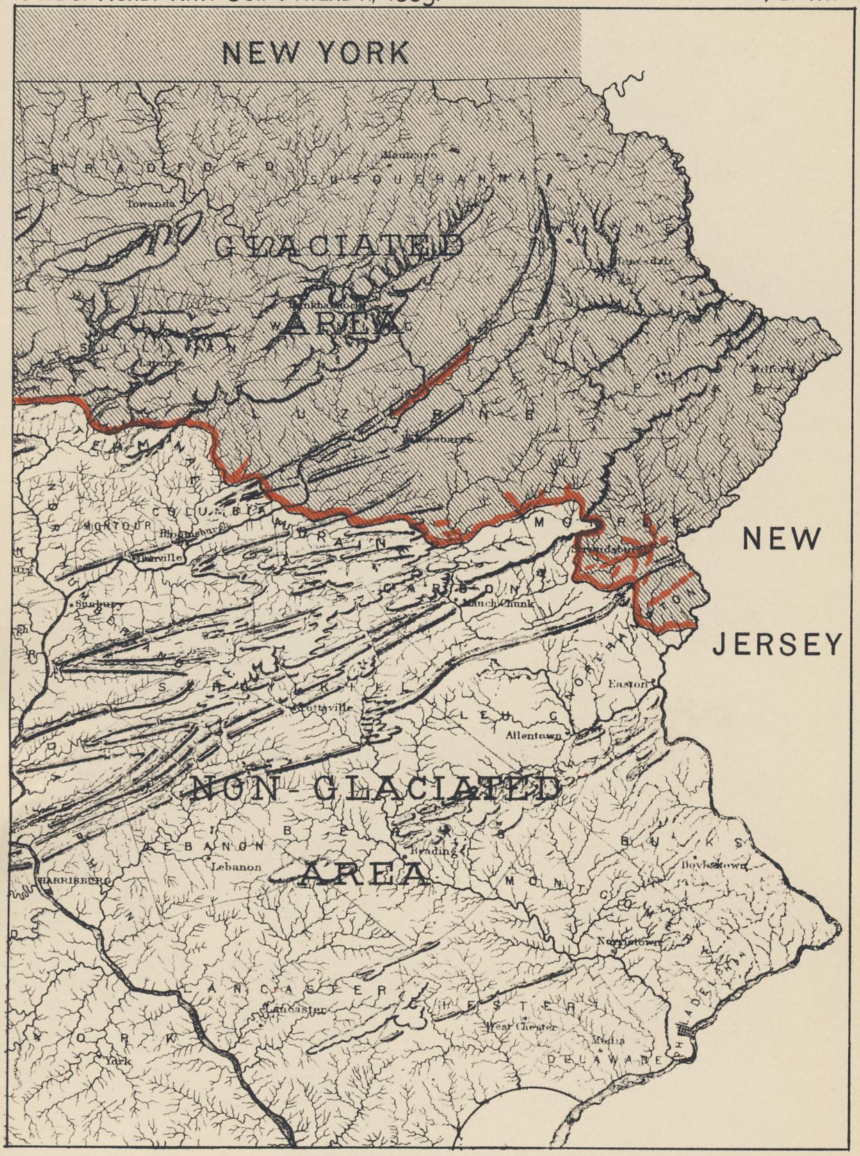
Since this paper was read at Montreal, Mr. J. H. Kinahan, of Dublin, who was present when the paper was read, has, in an article entitled "On the use of the term Esker or Kăm Drift" (Amer. Journ. Science, xxix, 1885, p. 135), criticized the pronunciation and use of the word kame by American geologists; while at the same time reaffirming his belief that "true esker or kăm drift" is "due to currents and eddies generated by the meeting or colliding of two or more currents in a mass of water, such as that of a sea or large lake." He argues that because of an ancient Celtic word "cam" or "kăm" meaning *crooked* or *winding*, we should pronounce the word kame short, as if spelled căm.

It is not probable that American geologists will adopt this short pronunciation. The word has long been pronounced kame both in England and Scotland, and in the latter country is often spelled *kaim*. Indeed Mr. Kinahan himself formerly used this spelling, and therefore also, the long pronunciation. (See his article "On the Drift in Ireland," Journ. Roy. Geol. Soc. Ireland, vol. i, p. 200, where he speaks of "eskers or *kaims*.")

The now antiquated idea that eskers and kames are due to oceanic or lacustrine currents has naturally enough been held in Ireland, where the land often lies but little above ocean level, but such a theory is untenable in America. Mr. Kinahan himself says, that the marginal kames of America must be quite different from the Irish eskers, and ventures the explanation that "there were at times 'flashes' or areas of shallow water accumulated margining the faces, portions of which were still water, while in other portions there were currents; or it might have been a mass of snow margining a narrow flash of flowing water." This explanation, like one held by Sir William Dawson (Proc. Amer. Assoc. Adv. Sci., xxxii, 1884, p. 25), that the terminal moraine simply marks the "limit of the deep water of a glacial sea," would probably be greatly modified had those geologists the opportunity of studying in the field the margin of the glaciated area of Pennsylvania.

How could any area of water, still or flowing, accumulate along the margin of an ice sheet which rests against an upward slope, as it so often does in this State? And if such areas of water did exist south of the moraine, why have not some relics of such a body of water been left in the shape of sand, gravel or clay? There is no fact in relation to glaciation more satisfactorily determined in the writer's "Report on the Terminal Moraine" than the absence of any body of water, deep or shallow, in front of the moraine. This unexpected fact is clearly shown by the entire absence of drift south of the moraine except in river valleys (the narrow glacial "fringe," elsewhere described, is excepted). While kames and many other deposits made by melting ice abound immediately back of the moraine, all these stop abruptly at the moraine, and the line of demarkation is at times so sharp that "it is almost possible to stand with one foot upon the glaciated and the other upon the non-glaciated ground" (Second Geol. Surv. of Pa., Z, p. 103).

The study of glacial phenomena is in a much more advanced stage in America than it is in Europe. To the smaller areas studied, and to the artificial changes which have modified the surface deposits of the Old World, are in great part due the limited views, the confusion of terms, and the contradictory theories which characterize much of the very voluminous literature of the glaciation of Europe. No better field for the prosecution of glacial studies can be found than in America, where single deposits extend for thousands of miles under varying conditions of mountain and valley, of flood plains and of prairies, and where in many places they stand to-day almost in the form in which they were originally made, untouched by the hand of man, and gently dealt with by that of time.



MAP OF

MARGINAL KAMES

IN EASTERN PENNSYLVANIA,

BY

H. CARVILL LEWIS.

The Terminal Moraine and Kames are marked in red.